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*TROPICAL AGRICULTURE is published monthly at the Imperial College of Tropical Agriculture, St. Augustine, Trinidad, West Indies. Advertisement and subscription rates can be obtained at the College from the Editor, or from the Secretary of the College, Grand Buildings, Trafalgar Square, London, S.W. 1, England. The Editor will be glad to consider authoritative articles for publication. It is understood that opinions expressed or recommendations made in signed articles or in articles of which the source is named are those of the author and do not necessarily represent the policy or opinion of the College Authorities. Increasing numbers of inquiries are being received from the various parts of the tropics which can be answered only by persons possessed of an intimate knowledge of local conditions. Enquirers should first satisfy themselves that their local Department of Agriculture is not able to supply them with the desired information before communicating with us. Correspondence which will be replied to is invited on all other matters pertaining to tropical agriculture, science and development.*

## PROGRESS IN FIELD STUDIES WITH INSECTICIDES *

DURING the past decade important advances have been made in all branches of entomology, but especially noteworthy has been the progress in field studies of insect and mite problems of agricultural crops. It is significant that greater emphasis is being placed on the quantitative aspects of these problems, particularly in relation to the evaluation of treatments and to the measurement of the effects of insect populations on the host plants.

The present emphasis on marketing of agricultural crops has been largely necessitated by fruitful research and the successful extension of information regarding production problems. Pest control is an integral part of the efficient production of many crops. Maximum yield of high-quality produce is the goal of the agriculturist. The consumer has been educated to expect fruits and vegetables to be practically free from insects, evidence of insect attack, and insecticidal residue. "Eye appeal" has become an important criterion of the purchaser. The federal and state regulations of the United States pertaining to the marketing of certain commodities have become rigid with respect to the presence of insects or their work, as well as of chemical residues. The recognition of the adverse effects of residues of certain insecticides on public health and on soils has stressed the need for materials that do not possess these undesirable characteristics. Furthermore, many injurious insect species have increased in importance with the increase in acreage of certain crops and intensified production efforts. Such trends have resulted in greater demand on the entomologists, not only for more economical and satisfactory measures of control but also for higher standards of control.

Old pests, such as the codling moth on pome fruits, the California red scale on citrus, and others for which control programmes until about twenty years ago were relatively simple and very effective, have become exceedingly difficult and expensive to control. Species formerly of minor importance and some of fairly recent introduction have assumed an economically important status. The increased number as well as the increased importance, of field entomological problems, has therefore been largely responsible for the relatively rapid development of economic entomology.

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With some of the larger and more important control problems, it is questionable, at least in the opinion of certain progressive growers whether we are even maintaining a position abreast of the problems, whereas our obvious aim is to get ahead of them and to keep the situation well in hand. It would be very gratifying, if entomologists in reporting on their work to growers could truthfully make the commonly seen press statement "offensive progressing according to plan." It is increasingly evident that if the expected progress in dealing with many of the field-control problems is to be made, it will be necessary to broaden the mode of attack and intensify the efforts of the various specialists participating in the study. The plan of group action is desirable and effective, but lack of funds or organization often partially or wholly prevent its utilization. Even the lone worker on the field problem is obliged to draw upon and utilize to the best of his ability the information developed by others in specialized fields. Since many important advances have been made in related fields of science, the field worker has a rich fund of information to draw upon, much of which may be applied directly or with modification and adaptation to his particular problem. The training of entomologists during the past decade has been greatly broadened, and, many of those with more modern training who undertake field studies are well equipped to do excellent work employing methods and techniques of only relatively recent origin.

Industrial organisations are playing a valuable rôle in the advances made in agricultural entomology. With their extensive resources, they have been able to synthesize thousands of new compounds many of which possess insecticidal properties. It is recognized that some of the most important older insecticides are failing to meet current needs. This fact, among others, has stimulated the intensive search for more effective materials. It is therefore of mutual interest that the potential value of new materials and combinations of materials be determined as fully as possible. After the "weeding out" process through biological assays in the laboratory, a number of the materials reach the stage of field testing and other phases of study.

With the increasing number of new materials and combinations of materials available for field evaluation and the need for critical comparisons of their performance, it is necessary to develop techniques or standardized procedures that afford the maximum efficiency and reliability in the appraisal of the merits and limitations of these materials. Consequently, it frequently happens that the development and validation of each step in the experimental procedure that is finally adopted requires more planning and actual work than the conduct of a single season's experiments for which the procedure is to be utilized. However, without satisfactory methods for conducting the experiments the data obtained may be inconclusive or meaningless. Since large-scale field-control studies are both expensive and laborious, it is consoling to the worker to know that in using a carefully worked out design he is proceeding on a sound basis and will likely conclude the experiment with data that are capable of being analyzed and used reliably in planning further studies. Even when the utmost has been done in plot design, measurements of population densities or their effects before and after treatments, chemical analysis of initial and residual deposits of the materials under consideration, and appraisal of the effect of the treatment on the plants exclusive of the effect of reducing the insect population, there are usually many remaining points on which additional information would be valuable.

In many instances the use of a certain insecticide on a given crop is a matter of compromise with respect to plant injury. For instance with HCN, which has been a standard treatment for the control of scale insects on citrus in California for over fifty years, unexplained instances of plant injury occur annually. Therefore in the search for new and more effective materials it is important, though often difficult, to determine fully the aspects of plant tolerance which should be known before a treatment that is otherwise satisfactory is either used extensively or discarded.

It may be stated that the increased demands for more effective control measures have been beneficial to entomology in that they have necessitated more extensive studies of a higher calibre than formerly. These demands, together with the availability of new materials and improved mechanical equipment for applying insecticides and the utilization of modern methods of study, have led to important advances. With co-operative effort the future should bring forth many more important accomplishments in our attempts to develop more effective, economical, and otherwise satisfactory control programmes for the insects and mites attacking agricultural crops.

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## MR. ERIC MACFADYEN KNIGHTED

We have learnt with deep satisfaction of the Knighthood which His Majesty the King has graciously been pleased to confer on Mr. Eric Macfadyen and desire to offer him our heartiest congratulations on this well merited honour. It is a fitting tribute to his distinguished services to the College in particular, and tropical agriculture in general.

Mr. Macfadyen was elected Chairman of the Governing Body of the Imperial College of Tropical Agriculture in 1937 in succession to the late Sir James Currie.

# THRIPS RESISTANCE IN CACAO

BY

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## Introduction

In recent years the development of plant varieties resistant to insect attack has attracted much attention as a method of pest control, and a number of comprehensive reviews have appeared of the considerable literature that exists on the subject. Resistance to thrips attack has been demonstrated in plants such as the onion and the gladiolus, in both of which it is attributed largely to a number of plant characters affecting the growth habit. The resistance of plant tissues to puncturing, due to hardness, thickness or toughness of the epidermis or other tissues, has been shown to be the underlying cause of resistance in many plants especially to certain sap-sucking insects. The onion thrips in attacking cotton prefers the undersides of the leaves, apparently because of a difference in epidermal thickness, and the same preference has been noted on the part of the bean thrips in feeding on its native hosts.

The cacao thrips (*Selenothrips rubrocinctus* Giard) is a native of tropical America, but is now widely distributed and occurs in most cacao-growing countries. It is an important pest of cacao in the West Indies, West Africa and Brazil. All stages of the cacao thrips live on the leaves and pods, and defoliation, which results from a severe attack, is the most serious aspect of thrips injury.

Control of the cacao thrips can be effected by the application of insecticides and, at any rate to some extent, by cultural measures such as increasing the overhead shade. A more permanent method of control, however, is particularly desirable for a pest of this type attacking a crop such as cacao grown on an extensive estate scale. Biological control of the cacao thrips in the West Indies by the introduction of the thrips parasite (*Dasyscapus parvipennis* Gahan) was originally suggested by Dr. J. G. Myers. In 1935 this parasite was introduced from the Gold Coast into Trinidad, where extensive liberations were made by Professor A. M. Adamson, but although now successfully established in Trinidad, Jamaica and Puerto Rico, it has not yet brought about any economic control of the pest. The planting of thrips-resistant varieties of cacao in those areas liable to severe thrips attack would be of great advantage to the industry, obviating the necessity of employing other control measures.

In the West Indies both planters and entomologists have on occasion observed outstanding individual cacao trees with very few thrips when surrounding trees were heavily attacked. Such trees may be said to exhibit an apparent thrips resistance, but probably few have any inherent resistance. Reports suggest that such trees are almost invariably poor bearers, and therefore undesirable types for selection and propagation. The existence of inherently thrips-resistant trees has been suggested among others by Pound (2), who states that there is a possibility of finding immune or resistant trees, for on several occasions planters have noticed that in badly stricken areas an occasional tree will stand out by retaining its leaves when all others are defoliated.

Thrips resistance is now reported in cacao, and methods used in finding and testing cacao for resistance are described in this paper. It appears likely that thrips resistance in cacao is due rather to the resistance of the cacao leaf to puncturing than to any plant characters associated with the growth habit.

## Field Selection of Thrips-Resistant Cacao

In 1939 studies were initiated on thrips resistance in cacao. The work was carried out in Trinidad, B.W.I., where, on account of its origin, the cacao is assigned to the Trinitario complex, probably one of the most heterogeneous cacao populations in the world and therefore an excellent one from which to make selections.

Three stages of procedure were adopted in the selection of thrips-resistant types. The first was to find trees among populations in the field which fulfilled the criteria of field selection for resistance. The second was to make a further selection based on the results of thrips resistance tests in the laboratory. The third was to make a final selection based on the results obtained when selections were subjected to thrips attack in the field.

Two main criteria of selection for thrips resistance in the field were laid down. These provided methods of field selection. The first criterion was fulfilled by trees which had withstood a severe thrips attack and retained their leaves when the surrounding trees were defoliated. This method of selection is of limited application. It can only be used following severe thrips outbreaks, such as occurred in the Montserrat Hills in 1938. Further, the retention of leaves by certain trees when the surrounding trees are defoliated, is probably attributable to a number of causes, other than freedom from thrips attack, which affect the normal metabolism of the tree and thereby inhibit leaf fall.

The second criterion was fulfilled by trees with few or no thrips on the leaves when the surrounding trees were heavily infested. This method of selection is similarly limited in application. It can only be used during the actual course of a severe thrips outbreak. Further, the presence

of few or no thrips on certain trees can be attributed to the normal distribution of the thrips population or to various environmental factors, which thereby confer an apparent resistance on these trees, rather than to intrinsic resistance.

In practice both methods of selection were used. It is thought, however, that *few or no thrips when surrounding trees are heavily infested* is a better criterion of selection for resistance in the field than *retention of leaves when surrounding trees are defoliated.*

A third method of selection, used to a very limited extent, was to find trees with leaves which were thick and leathery in texture and with no signs of thrips injury. This method is rather in the nature of a shot in the dark, being based on the fact that one of the definitely resistant types has leaves of this character. In the present state of our knowledge of the factors conferring resistance, this method can be used only with a limited chance of success.

The underlying cause of thrips resistance in cacao has not yet been adequately investigated, but it is thought to be due to the resistance of the cacao leaf to puncturing. It is not necessary, however, thoroughly to understand the underlying factors conferring resistance in order to initiate a selection programme. This lack of knowledge need not prevent selections from continuing to be made and tested for resistance by the methods described.

At first thrips-resistant types were selected with little regard to their potentialities as to yield. More recently, however, selections have been made with a view to finding desirable commercial types with high yielding capacity combined with thrips resistance. Notes have been kept on the selected types of the incidence of witches' broom disease, caused by *Marasmius perniciosus* Stahel. Witches' broom disease is widespread in South America and is much the most serious disease of cacao in Trinidad. The ideal to be attained is a good commercial type of cacao combining high yielding capacity with both thrips resistance and resistance to witches' broom disease.

Thrips-resistant trees were first searched for in the Montserrat Hills of the Central Range, and subsequent explorations have been made in other cacao-growing areas in Trinidad, including the Rio Claro, San Rafael and Sangre Grande districts, and also in Grenada. A total of 30 apparently resistant trees have been found and kept under observation. Two of the 18 trees found in 1939 have shown a marked degree of resistance. One of these (RT 18) appears to be a good commercial type of cacao, and the other (RT 17) is a very poor commercial type. Four trees were found in 1940, of which one (RT 20) has shown some degree of resistance, but is a poor commercial type. In 1941 seven trees were found, four being selected in Trinidad and three in Grenada. Of the Trinidad trees, one (RT 23) has shown a marked degree and another (RT 25) some degree of resistance, but both are comparatively poor commercial types. The Grenada selections have not yet been tested for resistance. One apparently resistant tree (RT 27) was found in 1942. It has not yet been tested for resistance, but appears to be a good commercial type of cacao.

Table 1 gives the criteria of selection for resistance in the field and the results of thrips resistance tests for the 30 apparently resistant types selected.

A severe thrips outbreak occurred towards the end of 1938 in the cacao-growing district of the Montserrat Hills of the Central Range extending from Flanagin Town to beyond Tabaquite, and almost all the cacao trees were completely defoliated. This provided an opportunity of searching for trees which fulfilled the first criterion of selection for thrips resistance in the field. Santa Severa estate at Brasso near the centre of the affected area suffered severely, and was chosen for a preliminary survey in 1939. Trees were searched for which had withstood the 1938 attack and were standing out conspicuously from their neighbours by retaining their leaves, when the surrounding trees were defoliated. A number of such trees were found.

Cuttings and budwood were taken from these trees for propagation, and leaf samples were taken for food preference tests in the laboratory. The trees were also kept under observation from 1939 to 1941 and thrips-population counts were made on them and on control trees immediately surrounding them. Leaf samples from none of these apparently resistant trees showed any marked degree of resistance when subjected to food preference tests by the leaf disc method in the laboratory. All these trees were attacked by thrips in 1939, 1940 and 1941 and appeared to suffer as much as their immediate neighbours. Thrips-population counts did not show any marked difference in infestation on these trees and on the control trees.

Trees were also searched for at Santa Severa estate which fulfilled the second criterion of selection and had few or no thrips when the surrounding trees were heavily infested. Four such trees were found. Two trees (RT 17 and RT 18) at the time they were originally found had no thrips when the surrounding trees were heavily infested.

Cuttings and budwood were taken from these trees for propagation, leaf samples were taken for food preference tests in the laboratory and the trees were kept under observation from 1939 to 1941, thrips-population counts being made on them and on the surrounding control trees.

In striking contrast with the results obtained for the earlier selections, RT 17 and RT 18 exhibited from the first great promise of resistance. Leaf samples showed a marked degree of resistance when subjected to food preference tests. The results were so encouraging that these selections were subjected to further thrips resistance tests in the laboratory in the form of obligatory food tests, and later to experimental field tests, which

**TABLE 1**

**Apparent Thrips-Resistant Cacao Types Selected in Trinidad and Grenada**

| Type | Date found | Estate | Locality | Criterion of Field Selection | Resistance shown in Tests |
|---|---|---|---|---|---|
| RT 1-8 | 22 June 1939 | Santa Severa | Brasso | Retention of leaves | *Non-Resistant* |
| RT 9 | 29 June 1939 | Santa Severa | Brasso | Few thrips | *Non-Resistant* |
| RT 10 | 29 June 1939 | Santa Severa | Brasso | Few thrips | *Non-Resistant* |
| RT 11-12 | 10 Aug. 1939 | Santa Severa | Brasso | Retention of leaves | *Non-Resistant* |
| RT 13-14 | 17 Aug. 1939 | — | Flanagin Town | Retention of leaves | *Non-Resistant* |
| RT 15-16 | 17 Aug. 1939 | San Juan | Caparo | Retention of leaves | *Non-Resistant* |
| RT 17 | 3 Nov. 1939 | Santa Severa | Brasso | No thrips | **Highly Resistant** |
| RT 18 | 3 Nov. 1939 | Santa Severa | Brasso | No thrips | **Highly Resistant** |
| RT 19 | 11 May 1940 | Santa Severa | Brasso | Retention of leaves | Tests not completed |
| RT 20 | 11 Oct. 1940 | Santa Severa | Brasso | Leaves thick. No thrips injury | **Resistant** |
| RT 21 | 25 Oct. 1940 | La Niña | Rio Claro | Retention of leaves | Tests not completed |
| RT 22 | 25 Oct. 1940 | La Niña | Rio Claro | Retention of leaves | Tests not completed |
| RT 23 | 5 Sept. 1941 | Las Hermanas | San Rafael | Few thrips | **Resistant** |
| RT 24 | 3 Oct. 1941 | Las Hermanas | San Rafael | Few thrips | Tests not completed |
| RT 25 | 24 Oct. 1941 | Corsica | Brasso | Retention of leaves | **Resistant** |
| RT 26 | 24 Oct. 1941 | Corsica | Brasso | Retention of leaves | Tests not completed |
| RT 27 | 9 Oct. 1942 | San José | Gran Couva | No thrips | Not yet tested |
| RT 101 | 13 Dec. 1941 | Boulogne | Grenada, B.W.I. | Leaves thick. No thrips injury | Not yet tested |
| RT 102 | 18 Mar. 1942 | Dougaldston | Grenada, B.W.I. | No thrips | Not yet tested |
| RT 103 | 18 Mar. 1942 | Dougaldston | Grenada, B.W.I. | No thrips | Not yet tested |

are described subsequently. Neither tree was attacked by thrips in 1939, 1940 or 1941, while neighbouring trees suffered severely and were partly defoliated as a result of thrips attack. Thrips-population counts showed a very striking difference in infestation on these trees as compared with the control trees.

Table 2 gives the thrips-population counts on RT 18 and on four surrounding control trees from November 1939 to December 1941. Counts for the four months April to July 1940 and for the same four months in 1941 gave very low values and have been omitted from the Table. Statistical analysis shows that the difference between the counts is very highly significant, and this difference is shown by all the controls. A difference so striking that statistical analysis is manifestly superfluous indicates that RT 18 is no ordinary tree and strongly suggests that it is highly thrips-resistant.

### Laboratory Tests for Thrips Resistance

Methods were devised for testing apparently thrips-resistant trees for resistance in the laboratory. Further selection was based on the results of these tests, which comprised (1) food preference tests with leaf discs, and (2) obligatory food tests with entire leaves and propagated budding and cuttings. Leaf discs, individual

**TABLE 2**

**Thrips-Population Counts on RT 18 and Control Trees in Thrips per 100 Leaves**

| Date | Control 1 | Control 2 | RT 18 | Control 3 | Control 4 |
|---|---|---|---|---|---|
| Nov. 1939 | 356 | 293 | 0 | 227 | 164 |
| Dec. 1939 | 281 | 226 | 4 | 139 | 143 |
| Jan. 1940 | 66 | 56 | 0 | 88 | 92 |
| Feb. 1940 | 40 | 44 | 0 | 56 | 38 |
| Mar. 1940 | 40 | 24 | 0 | 18 | 36 |
| Aug. 1940 | 5 | 40 | 0 | 80 | 4 |
| Sept. 1940 | 38 | 96 | 0 | 344 | 46 |
| Oct. 1940 | 111 | 96 | 0 | 217 | 189 |
| Nov. 1940 | 148 | 268 | 0 | 88 | 190 |
| Dec. 1940 | 52 | 30 | 0 | 48 | 170 |
| Jan. 1941 | 54 | 16 | 0 | 20 | 132 |
| Feb. 1941 | 54 | 52 | 0 | 12 | 116 |
| Mar. 1941 | 94 | 22 | 0 | 96 | 176 |
| Aug. 1941 | 34 | 18 | 0 | 14 | 40 |
| Sept. 1941 | 58 | 14 | 0 | 38 | 58 |
| Oct. 1941 | 40 | 12 | 0 | 72 | 84 |
| Nov. 1941 | 208 | 40 | 2 | 144 | 188 |
| Dec. 1941 | 40 | 8 | 0 | 136 | 128 |
| Mean | 95 | 75 | 0.3 | 102 | 111 |

The mean differences of 94.7, 74.7, 101.7 and 110.7 between thrips-population counts on RT 18 and Controls 1, 2, 3 and 4 respectively are highly significant at $P=0.001$.

leaves and propagated plants were inoculated with cacao thrips larvae obtained from the leaves of cashew (*Anacardium occidentale*). The larvae were transferred one at a time to the cacao to be tested by means of a fine damp sablehair paint-brush.

### Food Preference Tests

The food preference tests with leaf discs were of a preliminary nature and provided a method of roughly sorting out the types which had some inherent thrips resistance. In these tests a standard control type (ICS 1) was used for comparison, which is unfortunately rather susceptible to thrips attack. Other standard types, therefore, such as ICS 75 and ICS 22, were also used in later food preference tests.

In these tests the technique originally developed for cacao by Stephenson (3) and later used by Darling (1) was employed. Leaf discs were cut from the cacao to be tested and the comparative standard type. Only thoroughly hardened leaves were used, as far as possible of the same age for both the cacao to be tested and the standard type. Darling has shown that in food preference tests leaves from cacao trees growing in more intense light are significantly more attractive to thrips larvae. It is also of primary importance, therefore, that the leaves used should be taken from a part of the tree growing under approximately the same light intensity for both the cacao to be tested and the standard type. This was checked by means of a photometer of the rectifier cell type. Darling made light intensity measurements with this type of photometer at 50 Trinidad cacao sites, and obtained a mean light index of 73 for insolated stations and 18 for shaded stations. Shaded stations were under the normal canopy prevailing in Trinidad cacao. In practice leaves for the present tests were taken from trees growing under average normal shade conditions with a light index varying from about 10 to 30.

In the food preference tests alternate plot layouts were used, as there were only two treatments, the cacao to be tested being compared only with the standard type. Experiments were made with 3 x 3, 4 x 4 and 5 x 5 alternate plot layouts, using leaf discs 5, 4.8 and 1.8 cms. in diameter respectively. These layouts were duplicated, so that in a pair of 3 x 3 tests the plots were replicated 9 times, in the 4 x 4 tests 16 times and in the 5 x 5 tests 25 times. Eventually the 4 x 4 layout with leaf discs 4.8 cms. in diameter was found to be the most satisfactory and was used in all subsequent tests.

On being cut from the leaves the leaf discs were arranged with the upper surface of the disc uppermost on sheets of damp white blotting paper. Each disc was then inoculated with 10 first instar cacao thrips larvae. Each layout was covered with a large inverted glass petri dish 8½ ins. in diameter. After inoculation the larvae wandered for some time over the discs, the blotting paper and the inside of the petri dish, but later settled down on the discs and commenced feeding. To eliminate any stimulus due to light, all tests were carried out in darkness, the petri dishes being covered with black cloth. The subsequent distribution of the larvae was regarded as an indication of their preference for the leaves tested.

After 24 and 48-hour periods counts of the larvae were made on each disc. These counts were integrated into totals for the 8 discs of each treatment. In Tests 1 and 2 RT 18 was compared with ICS 1, and in Tests 3 and 4 with ICS 75. The layouts of Tests 1 and 2 and the subsequent distribution of the larvae are shown in Fig. 1.

Cacao thrips larvae, when actively feeding, bear at the end of the abdomen a drop of liquid excrement, which gradually increases in size as they feed until too large to carry, and is then deposited on the leaf, where it dries to form a small dark spot. As larvae do not tend to wander once a suitable part of the leaf has been found on which to feed, an enumeration of the excrement spots on the leaf provides a good indication of the extent of feeding.

In addition to counts of the larvae, the number of excrement spots on the discs was also counted. The results of Tests 1 and 2 are given in Table 3 and those of Tests 3 and 4 in Table 4.

**TABLE 3**

**Counts of Larvae and Excrement Spots after 24 and 48 hours Integrated into Totals for the 8 Discs of each Treatment**

| No. of Test | Date of Test | RT 18 | | ICS 1 | |
|---|---|---|---|---|---|
| | | No. of larvae | No. of excrement spots | No. of larvae | No. of excrement spots |
| 1 | 15-17 Jan. 1940 | 17 | 10 | 132 | 127 |
| | | 21 | 13 | 114 | 98 |
| 2 | 30 Jan.-1 Feb. 1940 | 15 | 8 | 123 | 92 |
| | | 13 | 8 | 135 | 97 |
| | Means | 16.5 | 9.7 | 126.0 | 103.5 |

The mean differences between counts of larvae and excrement spots on RT 18 and ICS 1 are highly significant at P=0.001.

**TABLE 4**

**Counts of Larvae and Excrement Spots after 24 and 48 hours Integrated into Totals for the 8 Discs of each Treatment**

| No. of Test | Date of Test | RT 18 | | ICS 75 | |
|---|---|---|---|---|---|
| | | No. of larvae | No. of excrement spots | No. of larvae | No. of excrement spots |
| 3 | 30 Jan.-1 Feb. 1940 | 16 | 14 | 96 | 77 |
| | | 17 | 16 | 89 | 73 |
| 4 | 4-6 Feb. 1940 | 12 | 12 | 99 | 56 |
| | | 9 | 6 | 110 | 72 |
| | Means | 13.5 | 12.0 | 98.5 | 69.5 |

The mean differences between counts of larvae and excrement spots on RT 18 and ICS 75 are highly significant at P=0.001.

**TEST 1**

| | | | |
|---|---|---|---|
| RT 18<br>3 | ICS 1<br>14 | RT 18<br>4 | ICS 1<br>15 |
| ICS 1<br>14 | RT 18<br>2 | ICS 1<br>22 | RT 18<br>1 |
| RT 18<br>3 | ICS 1<br>11 | RT 18<br>2 | ICS 1<br>18 |
| ICS 1<br>20 | RT 18<br>0 | ICS 1<br>18 | RT 18<br>2 |

Treatment totals :
RT 18=17 ICS 1=132.

| | | | |
|---|---|---|---|
| ICS 1<br>21 | RT 18<br>2 | ICS 1<br>19 | RT 18<br>4 |
| RT 18<br>1 | ICS 1<br>12 | RT 18<br>3 | ICS 1<br>15 |
| ICS 1<br>13 | RT 18<br>1 | ICS 1<br>13 | RT 18<br>2 |
| RT 18<br>5 | ICS 1<br>12 | RT 18<br>3 | ICS 1<br>9 |

Treatment totals :
RT 18=21 ICS 1=114.

The diferences between totals are highly significant at P=0.001.

**TEST 2**

| | | | |
|---|---|---|---|
| RT 18<br>4 | ICS 1<br>9 | RT 18<br>1 | ICS 1<br>16 |
| ICS 1<br>18 | RT 18<br>1 | I CS1<br>17 | RT 18<br>3 |
| RT 18<br>3 | ICS 1<br>11 | RT 18<br>2 | ICS 1<br>15 |
| ICS 1<br>19 | RT 18<br>1 | ICS 1<br>18 | RT 18<br>0 |

Treatment totals :
RT 18=15 ICS 1=123.

| | | | |
|---|---|---|---|
| ICS 1<br>28 | RT 18<br>2 | ICS 1<br>14 | RT 18<br>0 |
| RT 18<br>3 | ICS 1<br>27 | RT 18<br>2 | ICS 1<br>15 |
| ICS 1<br>16 | RT 18<br>2 | ICS 1<br>10 | RT 18<br>0 |
| RT 18<br>2 | ICS 1<br>12 | RT 18<br>2 | ICS 1<br>13 |

Treatment totals :
RT 18=13 ICS 1=135.

The differences between totals are highly significant at P=0.001.

**Fig. 1. Food Preference Test Layouts, RT 18 Compared with ICS 1, Counts of Larvae after 24 and 48 hours Integrated into Totals**

The conclusions to be drawn from the results of the food preference tests with leaf discs, as shown by the distribution of the larvae and excrement spots, are that thrips larvae show a significant preference to feed on the leaves of the standard control types rather than on those of RT 18. This suggests that RT 18 is inherently thrips-resistant.

### Obligatory Food Tests

The obligatory food tests differed from the food preference tests in that the thrips were given no choice of food material, but were obliged either to feed on the leaves supplied or to starve. These tests provided the most satisfactory method of assessing the thrips resistance of cacao types under controlled conditions in the laboratory. A few tests were carried out with leaves removed from trees. Thoroughly hardened leaves were used, as far as possible of the same age and growing under approximately the same light intensity for both the cacao to be tested and the standard type. The results obtained in these tests showed how thrips react to individual leaves of resistant and susceptible cacao when given no choice of food material. Subsequent tests with propagated buddings and cuttings provided data confirming these results.

In tests with leaves removed from the tree, $6\frac{1}{2}$ by $4\frac{1}{2}$ by $4\frac{1}{2}$ ins. glass jars with metal screw-tops were used. The jars had flat sides on which they were laid, and a leaf of the cacao to be tested was placed in each jar. Each leaf was then inoculated with 50 to 100 first instar cacao thrips larvae. Counts were made of the number of larvae present after 1 to 10 days. In the later counts prepupae, pupae and adults were recorded. A few tests were also made with thrips adults. Cacao leaves removed from the tree tend to become dry very rapidly, and for tests over an extended period it was necessary to renew them at least every other day. A high thrips mortality also occurred, due to the rather unfavourable conditions of the experiment. In order to minimize these disadvantages, a $5\frac{1}{2}$ by 4 ins. piece of damp blotting paper was placed in each jar with the cacao leaf.

A series of replicated obligatory food tests carried out in September 1940 with individual leaves of RT 18 and the standard types (ICS 1 and ICS 75) gave the following results. On RT 18 after 3 days the thrips larvae were small, dispersed on the leaves, did not appear to be feeding and did not carry drops of liquid excrement. There were few or no signs of any feeding marks and no

excrement spots were deposited on the leaves. After 5 days about 25 per cent. of the larvae were dead; those remaining were small and a few appeared to be feeding to some extent and to have drops of liquid excrement. There were some signs of feeding marks and a few excrement spots were present on the leaves. After 7 days about 50 per cent. of the larvae were dead. The remaining larvae were small; a few appeared to be feeding to some extent and carried excrement drops. A few undersized prepupae and pupae were sometimes present. After 10 days there were a few remaining small larvae, apparently suffering from starvation. A number of small prepupae and pupae and even a few small adults were present in some tests.

On ICS 1 and ICS 75 after 3 days the thrips larvae were normal in size and distinctly larger than those on RT 18. They were feeding together in groups on the leaves and carried drops of liquid excrement. There were definite and unmistakable feeding marks and numerous excrement spots were deposited on the leaves. After 5 days a few larvae were dead, but the majority were feeding actively on the leaves. There were sometimes a few prepupae and pupae of normal size. After 7 days a number of the larvae were dead, but those remaining were feeding actively. Numerous prepupae and pupae of normal size were present and there were sometimes a few adults. After 10 days there were very few or no larvae remaining on the leaves. There were numerous prepupae, pupae and adults of normal size.

A few tests made with thrips adults gave the following results. On RT 18 after 3 days about 50 per cent. of the adults were dead, after 5 days about 75 per cent. were dead and after 7 days about 90 per cent. were dead. Few or no eggs were laid. On ICS 1 and ICS 75 after 3 days about 10 per cent. of the adults were dead, and after 5 days and 7 days about 25 per cent. were dead. Some eggs were laid.

The conclusions to be drawn from the results of the obligatory food tests with individual leaves are that, in comparison with the standard types, thrips larvae and adults find RT 18 unpalatable and are unable to survive for long on its leaves.

In obligatory food tests with propagated buddings and cuttings, small cacao plants growing in baskets were used. Plants were chosen with about 15 fully hardened leaves, and any unhardened flush leaves were removed. All the plants used in these tests had been grown under uniform shade conditions with a light index varying from about 10 to 20, as measured by means of the photometer described above. Each plant was inoculated with 500 cacao thrips larvae, the majority of which were in the first instar. An attempt was made to inoculate each leaf on the plant with about the same number of larvae.

In these tests the standard type (ICS 1) was used for comparison. As there were only two treatments, the cacao to be tested being compared only with the standard type, alternate plot layouts were used. Experiments were made with 2 x 2, 2 x 3 and 3 x 4 alternate plot layouts, using 2, 3 and 6 replications respectively in each test. The tests were carried out in the laboratory and it was ensured that as far as possible the light intensity was the same throughout the layout. The relative positions of the plants were changed from time to time to obviate any differential stimulus due to varying light intensity. Counts were made of the number of larvae present after 24, 48 and 72-hour periods. A considerable number of larvae left the plants during the first 24 hours, and smaller numbers were missing in the succeeding 24-hour periods. In the later counts some prepupae were recorded, as a few second instar larvae were used for inoculation.

Obligatory food tests carried out in October 1940 with a 3 x 4 alternate plot layout with 6 replications of both RT 18 and ICS 1 gave the results shown in Tables 5 and 6.

**TABLE 5**

**Thrips-Population Counts on RT 18 and ICS 1 in Obligatory Food Tests**

| Type | Test No. | Thrips | | | |
|---|---|---|---|---|---|
| | | After 0 hours | After 24 hours | After 48 hours | After 72 hours |
| RT 18 | 1 | 500 | 219 | 187 | 148 |
| | 2 | 500 | 224 | 181 | 156 |
| | 3 | 500 | 232 | 197 | 173 |
| | 4 | 500 | 191 | 172 | 137 |
| | 5 | 500 | 238 | 204 | 154 |
| | 6 | 500 | 272 | 223 | 183 |
| | Mean | | 229.2 | 194 | 158.5 |
| ICS 1 | 1 | 500 | 337 | 279 | 262 |
| | 2 | 500 | 356 | 308 | 305 |
| | 3 | 500 | 441 | 434 | 425 |
| | 4 | 500 | 337 | 313 | 289 |
| | 5 | 500 | 413 | 408 | 389 |
| | 6 | 500 | 413 | 435 | 409 |
| | Mean | | 382.8 | 362.8 | 346.5 |

The mean differences of 153.6, 168.8 and 188.0 between thrips-population counts on RT 18 and ICS 1 after 24, 48 and 72 hours respectively are highly significant at P=0.001.

**TABLE 6**

**Mean Number and Percentage of Larvae Missing, Larvae Remaining and Prepupae Developing on RT 18 and ICS 1 in Obligatory Food Tests**

| Type | Thrips | After 0 hours | After 24 hours | After 48 hours | After 72 hours |
|---|---|---|---|---|---|
| RT 18 | Larvae missing | — | 270.8<br>54% | 306<br>61% | 341.5<br>68.5% |
| | Larvae remaining | 500<br>100% | 216.7<br>43.5% | 179.3<br>36% | 141<br>28% |
| | Prepupae developing | — | 12.5<br>2.5% | 14.7<br>3% | 17.5<br>3.5% |
| | Larvae and prepupae | 500<br>100% | 229.2<br>46% | 194<br>39% | 158.5<br>31.5% |
| ICS 1 | Larvae missing | — | 117.2<br>23.5% | 137.2<br>27.5% | 153.5<br>30.5% |
| | Larvae remaining | 500<br>100% | 361.5<br>72.5% | 320.3<br>64% | 264.8<br>53% |
| | Prepupae developing | — | 21.3<br>4% | 42.5<br>8.5% | 81.7<br>16.5% |
| | Larvae and prepupae | 500<br>100% | 382.8<br>76.5% | 362.8<br>72.5% | 346.5<br>69.5% |

The above results show that after 24 hours more than half (54 per cent.) of the thrips larvae on RT 18 had left the plants, as compared with less than a quarter (23.5 per cent.) of those on ICS 1. After 72 hours more than two-thirds (68.5 per cent.) of the larvae on RT 18 had left the plants, as compared with less than one-third (30.5 per cent.) on ICS 1. This suggests that the larvae find RT 18 less palatable than ICS 1.

An enumeration of the excrement spots on the leaves gave far smaller numbers for RT 18 than for ICS 1, indicating much less extensive feeding on RT 18. Further, after 72 hours some 16.5 per cent. of the larvae on ICS 1 had developed into prepupae as compared with 3.5 per cent. on RT 18. The few prepupae on RT 18 were undersized, suggesting that the larvae had been underfed. Such prepupae developed from a few second instar larvae, probably almost fully fed at the time of inoculation.

The conclusions to be drawn from the results of the obligatory food tests with propagated buddings and cuttings are that, in comparison with the standard type (ICS 1), thrips larvae find RT 18 unpalatable and unsuitable as food.

### Field Tests for Thrips Resistance

The third and final procedure adopted in the selection of thrips-resistant types was to subject selections to thrips attack in the field. Experimental field blocks of the cacao to be tested and the standard type (ICS 1) were established in various parts of Trinidad. The field blocks were laid down in areas liable to severe thrips attack, including persistant thrips pockets of long standing.

The first of these field experiments was planted in October 1940 at Santa Severa estate in the Montserrat Hills. An alternate plot layout was used, as there were only two treatments, the cacao to be tested being compared only with the standard type. The experimental block covered approximately 1/3 acre. It comprised 104 trees, there being 52 replications of both the cacao to be tested and the standard type.

It was originally proposed to plant cuttings of both RT 18 and ICS 1 throughout the block. Actually 50 buddings and 2 cuttings of RT 18 were planted for comparison with 52 cuttings of ICS 1. A nursery of RT 18 was established in 1940 to provide suitable material for the production of propagated cuttings, but such cuttings were not available for planting in the field until 1941 and 1942. In order to lay down the experiment in 1940, it was decided to plant RT 18 buddings propagated from budwood obtained from the original tree, rather than wait until RT 18 cuttings became available.

Thrips-population counts were made on the experimental block over a period of two years from 1940 to 1942. The standard type (ICS 1) had consistently a greater population than RT 18, and statistical analysis showed a highly significant difference between the counts. These results are shown in Table 7.

**TABLE 7**

**Coefficient of Resistance of RT 18 from Thrips-Population Counts on RT 18 and ICS 1 in Experimental Field Block**

| Date | RT 18 Thrips per 100 leaves | ICS 1 Thrips per 100 leaves | Coefficient of resistance of RT 18 |
|---|---|---|---|
| 29 Nov. 1940 | 6.9 | 59.1 | 0.88 |
| 13 Dec. 1940 | 9.1 | 36.1 | 0.75 |
| 31 Dec. 1940 | 11.7 | 120.5 | 0.90 |
| 17 Jan. 1941 | 8.2 | 65.2 | 0.87 |
| 31 Jan. 1941 | 13.1 | 74.7 | 0.82 |
| 14 Feb. 1941 | 20.8 | 93.2 | 0.78 |
| 28 Feb. 1941 | 5.5 | 25.7 | 0.79 |
| 4 Feb. 1942 | 29.0 | 138.5 | 0.79 |
| 4 Sept. 1942 | 4.8 | 90.0 | 0.95 |
| 2 Oct. 1942 | 4.7 | 90.7 | 0.95 |
| 6 Nov. 1942 | 9.8 | 136.5 | 0.93 |
| 5 Dec. 1942 | 15.2 | 113.6 | 0.87 |
| Mean | 11.57 | 86.98 | 0.867 |

The mean difference of 75.4 between thrips-population counts on RT 18 and ICS 1 is highly significant at P=0.001.

The first thrips-population counts were made in November 1940 soon after the block was planted and were continued until February 1941. The trees were very small and it was not possible to examine more than about 5 to 10 leaves on each tree. Only fully hardened leaves were examined for thrips. Some 200 to 300 leaves altogether were therefore examined on each type. After February 1941 the thrips population fell considerably and maintained a constantly low level for about twelve months. During this period counts were occasionally made. Thus, on 14 March 1941 the population was 3.9 thrips per 100 leaves on RT 18 and 12.0 thrips per 100 leaves on ICS 1. On 14 November 1941 counts gave 2.1 thrips per 100 leaves on RT 18 and 17.3 thrips per 100 leaves on ICS 1. These counts were regarded as too low for comparison of RT 18 and ICS 1 and have therefore been omitted from the Table.

The fall in the thrips infestation and the maintenance of the population density at a low level for about twelve months was most unfortunate from the point of view of the experiment. Confirmatory data, to support the preliminary counts, made from November 1940 to February 1941, were not obtained from the experimental block until a year after they had been expected.

Thrips populations normally start to increase rapidly in Trinidad as the rainy season progresses, reaching a maximum in about November, when the main attack takes place, and then decreasing. A sudden increase in the population during the dry season from January to April often occurs, and the population density may sometimes attain as high a level as that recorded in November. Dry season infestations, unlike the main attack which may last for two to three months, are rarely maintained at a high level for more than two to three weeks and seldom result in serious damage.

In the experimental block the normal main attack did not develop during the rainy season in 1941. A count made in February 1942, however, showed a surprisingly high thrips population, some six times greater than that occurring in the same month of the previous year. This fell considerably in March and by April few thrips were to be seen. From April to August 1942 a constantly low population was maintained as in the previous year.

Thrips-population counts were renewed in September 1942. The trees were considerably larger after nearly two years' growth, and it was possible to examine at least 25 fully hardened leaves on each tree. Some 1,000 leaves altogether were therefore examined for thrips on each type. Counts made from September to December 1942 were disappointingly low. In January 1943 there were few thrips on the experimental block, and counts were therefore discontinued. It is proposed to renew them in about September 1943.

The experimental block has, therefore, unfortunately not yet been subjected to a severe thrips attack. It is hoped from the experimental point of view that a more severe attack will develop in 1943, so that confirmatory data can be obtained to support the counts already made. The results from counts on one and two-year old trees may differ from those on older trees on account of variability in thrips susceptibilty due to age. Further, the results obtained with low population densities may differ from those obtained with high densities. Neither of these possibilities, however, seems at all likely. Counts will nevertheless be continued in 1943 and in subsequent years. Other experimental blocks have also been established in various places in Trinidad known to be severely attacked every year. Counts will be made on these blocks in order to augment the results so far obtained by data from other areas.

### Coefficient of Resistance

The thrips resistance of a cacao type can be expressed quantitatively either as the ratio of the thrip population on the standard to that on the resistant type, or as the coefficient of resistance. The standard type (ICS 1) is highly susceptible to thrips and is therefore assumed to have a coefficient=0. A completely thrips-resistant or immune type would have a coefficient =1. The coefficient of resistance is based on the assumption that the standard type has a coefficient=0 and an immune type a coefficient =1, and is given by :

$$\frac{\textit{Population on standard type} \text{ less } \textit{Population on resistant type}}{\textit{Population on standard type}}$$

Thrips-population counts on the experimental field block showed that ICS 1 had on the average a population more than 7.5 times that on RT 18. The coefficient of resistance of RT 18 varied from 0.75 to 0.95 with a mean coefficient=0.87 (*see* Table 7).

### Description of RT 18 Cacao

RT 18 is a mature tree growing on Brasso Clay soil at about 500 feet altitude in the Montserrat Hills of the Central Range in a rather exposed position. It is a tall tree with a large head of foliage, standing out conspicuously from its neighbours, and occupying a ground area of about 16 by 16 ft. The leaves are dark green and rather small, with a slight tendency to curl at the edges, and are distinctly thick and leathery in texture. The tree appears to flush less frequently than the surrounding trees. It comes into bearing early in the season.

During the crop 1939-40 it produced 80 pods, 75 per cent. of the crop being picked from January to March. During the crop 1940-41 it also produced about 80 pods, the maximum bearing being from December to February, when 90 per cent. of the crop was picked. The pods are long,

oval, smooth and dark red, measuring about 17 cms. in length and 8.5 cms. in diameter. The shell is of medium thickness measuring 1.2 to 1.6 cms.

A sample of 60 pods taken at 3 periods in January, February and March 1940 gave a mean bean number of 38 and a weight of wet cacao of 98 gms. A standard sample of 30 pods taken at two periods in January and February 1941 gave a mean bean number of 39 and a weight of wet cacao of 109 gms. The beans are dark purple and rather small, weighing on the average only 2.8 gms. The standard sample gives a pod value of 10 pods to the lb. of dry cacao. On this basis the tree is producing 8 lbs. of cured beans per annum at the rate of over 12 cwts. per acre. It can therefore be regarded as a good commercial type of cacao, well above the Trinidad average.

## Conclusions

Thrips resistance in cacao appears to be attributable rather to the resistance of the cacao leaf to puncturing than to any plant characters associated with the growth habit, such as have been reported as the factors responsible for thrips resistance in the onion and the gladiolus.

Although the underlying cause of thrips resistance in cacao has not yet been thoroughly investigated, a selection programme has been initiated. The ideal to be attained is a good commercial type of cacao combining high yielding capacity with both thrips resistance and resistance to witches' broom disease.

Thrips-population counts on several selected and surrounding control trees in the field showed statistically significant differences, suggesting that the selections are thrips-resistant. Food preference tests with leaf discs in the laboratory also suggested that the selections are resistant, thrips larvae showing a significant preference to feed on the leaves of the standard control types rather than on those of the selected types. Obligatory food tests in the laboratory with individual leaves showed that, in comparison with the standard types, thrips larvae and adults find one of the selected types (RT 18) unpalatable and few larvae are able to complete their development on it. Similar results were obtained in tests with propagated buddings and cuttings of RT 18. Thrips-population counts over a period of two years on an experimental block established in the field showed that ICS 1 had consistently a significantly greater population than RT 18.

Thrips resistance is claimed for RT 18, a good commercial type of cacao, which is therefore recommended for planting on an experimental scale in areas liable to severe thrips attack.

## Summary

1. Methods of field selection of cacao resistant to the cacao thrips (*Selenothrips rubrocinctus* Giard) are described.

2. Of the 30 apparently resistant trees selected, 27 were found in Trinidad and 3 in Grenada.

3. RT 18 is the outstanding selection made, being not only thrips-resistant but also a good commercial type of cacao.

4. Thrips-population counts on RT 18 and four surrounding control trees are given. Statistical analysis shows that the difference between the counts is highly significant, suggesting that RT 18 is thrips-resistant.

5. Laboratory tests for thrips resistance are described. These took the form of food preference tests with leaf discs and obligatory food tests with entire leaves and propagated buddings and cuttings.

6. Results are given of food preference tests with RT 18 and standard control types. Thrips larvae showed a significant preference for the standard types rather than RT 18, suggesting that the latter is thrips-resistant.

7. Results are given of obligatory food tests with entire leaves and propagated buddings and cuttings. Thrips larvae (and adults in the case of entire leaves) found RT 18 less palatable than the standard type (ICS 1), and most of the larvae died or left the leaves before completing their development.

8. The establishment of an experimental field block of RT 18 and ICS 1 is described. Thrips-population counts over a period of two years showed that the standard type had consistently a significantly greater population than RT 18, the population on the former being on the average more than 7.5 times that on RT 18.

9. A method is given of expressing the thrips resistance of a cacao type as a coefficient of resistance. The mean coefficient of resistance of RT 18=0.87, based on the assumption that the susceptible ICS 1 has a coefficient =0 and an immune type a coefficient=1.

10. It is claimed that RT 18 combines thrips resistance with high yielding capacity, having a pod value of 10 pods to the lb. of dry cacao and a yield of over 12 cwts. of cured beans to the acre.

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## References

(1) Darling, H. S. (1942) The effect of light on the incidence of cacao thrips. *Tropical Agriculture*, Trinidad, **19** : 151-162.

(2) Pound, F. J. (1939) The cultivation of cacao on loam soils. Trinidad and Tobago : 29.

(3) Stephenson, P. R. (1938) The effect of potassium and phosphorus on the susceptibility of cacao to cacao thrips (*Selenothrips rubrocinctus* Giard). *Dissertation* I.C.T.A., Trinidad (unpublished).

# MIXED FARMING

## The Basis of a System for West Indian Peasants

BY

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The welfare of the British West Indies is dependent on agriculture and in a high degree on export crops. Both birth and death rates are high, but at the present natural rate of increase the population will be doubled in something like forty years. At various times over a long period of years, the construction of the Panama Canal, the banana plantations of Central and South America, the oilfields of South America, the oil refineries of Aruba and Curacao, the cane fields of Cuba and Santa Domingo, the United States of America and a host of minor outlets provided opportunities for emigration of which thousands took permanent advantage. These outlets had, however, been steadily closed, one after another, before the outbreak of the present war. No one can foretell whether any new outlets will appear, or whether any old ones will be re-opened; but it is clearly impossible for policy to be based on the expectation of future emigration on the old scale.

In these circumstances the West Indian Royal Commission of 1938-39 recommended in 1940 (Cmd. 6174, page 20 para. 20), as follows:

. . . "The outstanding agricultural need in the West Indies is more intensive use of the land with increased production of food in order to support a rapidly growing population. The most urgent need is the development of peasant agriculture, . . . The practice of shifting cultivation by peasant farmers must be abandoned and replaced by an organised system of permanent mixed farming;"

The Commission then proceeded to emphasize the necessity for new knowledge on which these reforms may be based, and to outline the directions which the researches and investigations should take. Here we are chiefly concerned with the following recommendation:

"21. (*d*) (iii) survey of peasant agriculture, and investigations for the purpose of devising better peasant farming systems based on mixed farming and* the complementary use of livestock and crops;"

Several other recommendations are more general and refer to both estate and peasant agriculture: of these the following is particularly germane to our present subject:

"21. (*g*) Since from a medical point of view a better-balanced diet is everywhere necessary, one of the first aims of agricultural reform must be a great increase in home production of foodstuffs which are not only adequate in quantity but suitable in quality, and should include milk, fish, eggs and green vegetables"

To facilitate discussion it therefore seems not improper to regard the Commission's recommendations concerning peasant agriculture as comprising three main principles:

(*a*) Expanding peasant agriculture,
(*b*) Devising a system of mixed farming for peasants,
(*c*) Increasing the production of food.

It is under these three heads that we develop our discussion.

### Expansion of Peasant Agriculture

The expansion of peasant agriculture is a question of policy having social and political facets with which we are not concerned. We merely note that most West Indian Governments have accepted the extension of small holdings as one of the means whereby a livelihood may be ensured to increasing numbers. Our main interest lies in the technical aspects of the prospective system of mixed farming; but it would be a waste of effort to evolve a system of mixed farming which the peasant could not practise because of some defect in his holding. An examination of existing smallholdings reveals both the need for mixed farming and the obstacles which would prevent its adoption.

Most of the land best fitted for agriculture has long been alienated; and if provision is to be made for additional numbers of small holders, their land must be acquired, in the main, from existing private owners. The West India Commissions of 1897, 1929 and 1938, each in turn, recommended the respective Governments to take powers for the compulsory acquisition of land for settlement purposes, but none went so far as to contemplate the dispossession of owners who make good use of their properties. Properties not beneficially utilised by their owners consist, for the most part, of marginal or sub-marginal lands, offering only a remote prospect of profit when worked with wage-paid labour. It is therefore probable that peasant holdings will often be characterised in the future, as they are at present, by low natural fertility, inferior climate, steep slope, inaccessibility, or some similar defect.

The gross out-put per acre from existing West Indian small holdings is generally much lower than that from estates. The yield of sugar from peasant holdings, for example, is little more than half that obtained by estates. This is in contrast to the experience of Great Britian where the gross output per acre is greater on small, than on large, farms.† The relatively low yields of the

* The word "*and*" is clearly a misprint for "or" because "mixed farming" and "complementary use of livestock and crops" are synonymous.

† Though the net output or profit per acre in England is usually less on small than on large farms.

West Indian peasant are due to the inferiority of his land, and the much less intensive system of cultivation he generally practises. The peasant customarily applies to the soil far less manure, whether organic or inorganic, than does the planter. Estate yields of sugar cane were maintained, in some cases for as long as 300 years, by a system which was essentially that of mixed farming. The peasant, too, owns livestock and thereby possesses an essential ingredient of mixed farming, but he can rarely claim to practise it. His ratio of 'cattle units' to cultivated acreage is usually smaller than that of the estates, but the more important difference is that very little farmyard manure finds its way from the peasant's animals to his land. Defective forms of land tenure are partly responsible for the apparent reluctance of small holders to apply farmyard manure to the land, but the major obstacle is a physical one.

Only a minority among West Indian peasants control undivided holdings of adequate size. India has witnessed the progressive fragmentation of holdings caused by increased pressure of population on the land and by practices associated with the Hindu law of inheritance.* Lack of capital and opportunity have compelled the West Indian peasant to build up his holding in fragments; but the effect is the same. He almost invariably owns a house, often in a village, and usually controls two or more parcels of land, frequently under different forms of tenure. He may keep his animals on one of his parcels of land, or, equally likely, entirely away from his land, either on a communal grazing ground or around his house. One, two, three or even more miles may separate his livestock from his land. Few peasants, except substantial cane farmers, own carts. The distance over which it is feasible for a man to head or crook farmyard manure must be measured in yards, not in miles. Even for the cart owner, a distance measured in miles is too great. Many West Indian small holdings have never received farmyard manure, and very few have received it regularly. Artificial fertilisers are rarely used.† Relentless cropping has greatly degraded much of the land under peasant control.

Livestock has served the West Indian peasant in various ways, as a savings bank, as an intermittent source of income or food, as a means of locomotion and transport, but too seldom as a manufacturer of humus and fertility for the land. Yet if provision is to be made for a rapidly increasing population without deterioration—or better, with a rise—in the standard of living, then fertility must not merely be maintained, it must be increased. In this endeavour livestock must play an important, even an indispensable, part. The provision of undivided holdings of adequate size, and of reasonable fertility, on which both the peasant family and the animals shall live, is an indispensable preliminary to the amelioration of West Indian peasant agriculture. But the provision of such holdings, the building of houses, the acquisition of livestock, the supplying of water for man and beast, and the development of the land constitute an expensive undertaking. The improvement of peasant agriculture is thus not only a social and political question, but also a financial problem as well as a technical one.

* As also in Trinidad among East Indians.

† It is worthy of note, however, that peasants show no reluctance to use artificials when they can be obtained on credit at reasonable terms.

**Devising a System of Mixed Farming**

The Royal Commission recommends "devising better peasant farming based on mixed farming." Most peasants will find it necessary to augment the number of their livestock in order to ensure an adequate supply of farmyard manure. But if the peasant were to forego communal grazing grounds, because of their distance, and to rely on roadsides and waste land alone, he would be compelled to reduce his head of livestock instead of increasing it. It is unlikely that he will be able to rely extensively on imported animal foodstuffs because of his perennial shortage of cash; so he must grow them. Now to divert land of reasonable fertility from either exchange or consumption crops which are capable, even with existing methods, of producing a gross annual income of the order of £5 an acre (pre-war figure) to the production of food for animals, will appear to the West Indian peasant to be just ludicrous. His reluctance to do so will not be entirely unreasonable, because, after all, an acre grown in crops for human consumption will feed many more people than an acre of grass or crops converted by animals into flesh foods. Yet it would appear that he must do so to enable him to cultivate his land at all.

The certainty of increasing pressure of population on the land necessitates the production of animal foodstuffs on an intensive system. The growing of annual crops, whether they provide concentrates for cattle, or bulk fodder, or both will not provide a solution, because such crops need to receive back again all the farmyard manure produced from their consumption, if the fertility of the land is to be maintained. For even on flat land in the wet tropics the need for manure, or at least for farmyard manure, depends not so much on what the crop takes from the soil as upon the frequency with which the soil is exposed and tilled. On sloping or steep land this relationship between frequency of cultivation and need for farmyard manure is the basic factor which should determine the farming system. As with many fundamental generalizations about tropical agriculture (or any other agriculture for that matter), it is impossible to quote concise figures to prove on paper a truth which seems self-evident in practice; but we believe that, in the wet tropics, if any particular crop, of whatever kind it may be, occupies the land for no more than six months, then to maintain the physical structure of any ordinary soil, it is necessary to put back all the

farmyard manure (or more) that could be made by giving the whole of that crop, grain and straw, to cattle as food or bedding. This difference between farming in the wet tropics and in either temperate or semi-arid sub-tropical climates cannot be over-stressed.

It therefore seems clear that the system of mixed farming which is to be devised for the West Indian peasant will have to be very different from that which has been successfully introduced in Northern Nigeria (1), by which the cattle are fed on crops grown in rotation on the same land as the main crops, or on the by-products of the main crop. The West Indian peasant's system must be one in which a part of the land is set apart to grow permanent, or nearly permanent, fodder crops, the farmyard manure produced by feeding the fodder being used on the other portion of the land where the main crops are grown. It is obvious that under such a system artificial manuring of the fodder crop will be necessary.

We believe that very important differences in detail between the systems of mixed farming in the sub-tropics and in the wet tropics will be necessitated by the fact that in the wetter climate an acre of any particular field crop needs vastly more manure than an acre of a similar crop in a dry climate like that of Northern Nigeria. An all-important factor in the success of mixed farming in that country has been the remarkably great increases in the yield of arable crops which result from very small dressings of farmyard manure. There, a dressing of three tons per acre once in the three years' arable rotation gives yields vastly superior to those that can be grown on un-manured land. Indeed, that small quantity of manure promises to maintain the fertility of many soils at a fairly satisfactory level without the addition of any other manure. Thus one ton of farm-manure per acre per annum may be said to be as effective in Northern Nigeria as the old standard dressing of 20 tons per acre once every four years was in England. Although there is no experimental result that can be quoted regarding the regular use of farmyard manure on arable rotations in the wet tropics, we believe that no experienced person will doubt that the rate of manuring needs to be somewhat greater there than even in England, and thus vastly greater than the very light dressings that have proved so remarkably effective in Northern Nigeria.

Two important consequences may be deduced from the contrast we have drawn between the British West Indies and Northern Nigeria. First, the density of livestock, and therefore the ratio of fodder crop to arable land, must be relatively high in the wet tropics. Secondly, there is every reason to expect that in the wet tropics the use of artificial manures will prove to be as economic for the peasant as it already is for the sugar planter. We believe that a considerable use of artificial manures will soon be found, when the experimental study begins, to be an almost essential feature of profitable mixed farming in the wet tropics. And if artificials are to be used by the mixed farmer at all, then it seems equally certain that the fodder should have first claim upon them. Their use there should enable the peasant to maintain his fodder crop in high productivity, in order that he may be compelled to incur the heavy expense of establishing new fodder only at long intervals of time. Artificials will, in all probability, also be profitable on the arable crops, thereby reducing the quantity of farmyard manure they would otherwise require: for many soil types in the wet tropics are very seriously deficient in either phosphate or potash. In fact we may come to regard farmyard manure primarily as the means of keeping the arable land in a healthy, cultivable, physical condition; and thus making it possible to grow upon it crops which will derive the greater part of their nutrients from artificial manures, always indirectly through the grass and sometimes even directly also.

We have noted that mixed farming is profitable in Northern Nigeria because of the great increase in yield which is derived from a small quantity of farmyard manure. Now if the quantity of manure needed by arable crops in the British West Indies is as large as we suggest, it is reasonable to question whether mixed farming is at all practicable there. The answer lies in the great difference between the two areas in the gross value of the return per acre which can be expected from reasonably well-manured land. The Agricultural Department of Northern Nigeria before the war regarded £2 as about the maximum reasonable monetary evaluation of the produce from an acre of such land. The corresponding figure in the British West Indies for a staple crop such as sugar cane can be put at not less than £10. Thus mixed farming is profitable in Northern Nigeria largely because of the high response in yield to farmyard manure and despite the low unit value of that increased yield; whereas the system may prove profitable in the British West Indies because of the high value of each additional unit of yield, and despite the relatively low increase in yield for a given quantity of farmyard manure.

We have spoken, so far, of "permanent fodder". "Permanent fodder" in the wet tropics, in so far as concerns the immediate future, will be substantially synonymous with "permanent grass". Many possible long-term tropical leguminous fodders have been tried from time to time, in the hopes of finding one which can take the place of lucerne or clover in sub-tropical or temperate zone agriculture. The trials continue and must continue; for the value of such a crop to tropical animal husbandry would be so great that it deserves continued trial. One or two relatively "new" ones are under trial at the

(1) *Trop. Agriculture*, XIX, No. 1, Jan., 1942, p. 17. "Mixed Farming in the Tropics: a Definition of the Term."

farm of the Imperial College of Tropical Agriculture, but there is as yet no crop of this kind that can be called a tested and proven success, in the sense that it can yet be recommended to peasants.

In the tropics there are three possible systems of growing and using permanent grass,

(*a*) the relatively unimproved, natural grazing, containing many species of grass or other plants ;

(*b*) the cultivation of the very tall permanent planted grasses, of the elephant grass type, for stall feeding ;

(*c*) there is an intermediate method, which is at least possible in some circumstances, by planting, as a single-species pasture, a grass of moderate size like Para grass, or molasses grass, suitable for controlled grazing or soiling.

Usually the natural, unplanted, many-species grazings in the tropics are nothing more than waste ground, of which a large part is covered with bushes and valueless weeds, another large fraction is bare, and the remainder is covered with coarse valueless grass, among which the cattle seek, and over-graze, the few plants of nutritive and palatable kinds.

It must be confessed that the improvement of natural, many-species pasture has not been experimentally studied anywhere in the tropics; and the great advance made in regard to pasture management in temperate climates in recent years naturally encourages the question "Why not also in the Tropics?" The authors believe that the improvement of such grazings in the tropics would be a vastly more difficult problem than in the temperate climate. This is primarily because, in the tropics, the farmer is denied the advantage of an essential factor in pasture management, namely, cutting the grass when there is more than the stock can eat and making it into hay for use in seasons when grazing is poor. If, by long continued intensive study of the problem on experiment stations, a system could be evolved for the maintenance and improvement of such grazings without haymaking, it is unfortunately probable that the system would be beyond the capacity of any peasant to sustain.

The second method mentioned above is that of cultivating grasses which are planted as a substantially permanent crop, for use in stall feeding. This method has been studied on the farm of the Imperial College of Tropical Agriculture in Trinidad for a number of years and it has also been tried out in other tropical countries. There seems to be nothing in the system that would be beyond the capacity of a West Indian peasant. The grass has to be weeded at least once a year ; but such tall grass is fairly effective in smothering weeds and, consequently, the amount of weeding required is not great. To obtain satisfactory yields, the grass must be frequently, and rather highly, manured with artificial manures, including nitrogen as well as phosphates and/or potash, in accordance with the characteristics of the soil. Cutting at the right height from the ground is important. But such grasses are distinctly hardy, and if the peasant's practices fall somewhat short of perfection for a time, the grass will not be quickly killed out. Again these tall grasses, if they are to yield fodder of maximum nutritive value and palatability, must be cut regularly at intervals of some six to ten weeks ; but if the cutting is delayed for even several weeks too long, it only means that the fodder is less valuable, not that the crop is permanently ruined. If, for one cause or another, some stools of grass are lost, they can be supplied at the expense of a little labour. Fencing is unnecessary with such grass and it can be grown on a strip-cropping system or on anti-erosion contour banks among other crops.

As an immediate practical measure, this system has the great advantage that enough knowledge and experience have been gained for it to be used as the basis of experiments in mixed farming. It is reasonable to assume that such grasses could be grown, with greater or less success, wherever sugar cane can be grown ; and sugar cane was at one time so much the staple crop of the West Indies that they were known as the "sugar colonies". Such grasses might, indeed, be grown in some places that are unsuited to sugar, since they do not require a ripening period.

All this does not of course mean that there is nothing more to be learnt about these grasses. There are many important matters which still need more investigation. One is the selection of the best species of this type of grass for different places in accordance with variations of soil and climate. Another is the question of silage to tide over the dry season in those districts in which the dry season is too long and too severe for the fodder requirements to be met entirely by the standing crop—which in practice probably means wherever there is annually an almost completely dry period of more than twelve weeks' duration. Another important point, about which nothing is known in regard to such grass, is its effect, after say five or ten years, on the fertility of the soil, which must determine the question of whether it is advisable to grow the grass as an entirely permanent crop or as a long lea which is dug up after a period of several years, and the land then used for other crops.

The obvious disadvantage of this "soiling system" of stock feeding is that the bulky fodder has to be carried in from the field to the farm building, and the bulky farmyard manure has to be carried out to the field where it is to be used. But if the grass, the pen and the crop land are contiguous, the distance on a peasant holding would be only a matter of yards—a very different proposition from the mile or more now frequently involved. The cutting and carrying of fodder is a daily task of fairly short duration, and there are indications that this kind of labour is hardly counted as labour by the peasant.

The third, or intermediate, system—the single species pasture—must be a matter for long-term, rather than immediately practical, experimentation.

The Guinea grass "pens" of Jamaica and the "Sour Grass" meadows of Barbados are hardly used intensively enough to come into this category. On an exceptionally damp soil, Para grass will give a heavy yield, and if at all reasonably managed will remain as a substantially pure stand. It is possible that other grasses may in time be found which will be similarly successful on drier, light land in the wet tropics; but this remains to be seen. On such a pasture, the production on each square yard should be heavy enough to make it reasonable to graze cattle by tethering them for a few hours each day. If this were done, the manure made during the remainder of the day would be available for the rest of the farm. Under the tethering system, it might be possible to control the grazing sufficiently well to maintain the pasture in fair condition; at least it can be said that the management of such a grass field would not call for such meticulous care and nice judgment as would the efficient management of a "natural", many-species, tropical pasture. At times when the grass has to be cut, it might be possible to make silage of it.

The great advantage of this system, if it were feasible, would be the avoidance of the carriage of the heavy fodder; but there would be difficulties in respect of bedding. For if the cattle be grazed for only part of the day, bedding will have to be cut, possibly even specially grown, and carried to the buildings, if any adequate quantity of farmyard manure is to be made; whereas under the soiling system, if the grass is fed whole to the cattle, the stalks and coarser portions which they reject provide ample bedding.

Our present knowledge about the use and management of any medium-sized, planted tropical grass is only slight; but it is enough to show that such grasses are rather closely dependent on climate and soil; the range of conditions in which any one particular species of this kind of grass will succeed will probably be found to be much narrower than in the case of particular species of soiling grass.

If the various premises which we have used are correct, and if the various opinions which we have based upon them are sound, we arrive at the conclusion that a practical system of mixed farming for peasants in the West Indies will be based essentially on the growing of tall fodder grass like elephant grass or Guatemala grass which is cut at intervals of six or ten weeks and carried to the byre. The grass will be regularly manured with artificial manures, which are peculiarly suitable for these crops. The farmyard manure will not generally be used in the standing grass, because that would entail heavily cultivating the land between the grass stools, which, from rather limited experience in Trinidad, seems to have a deleterious effect on the grass. Moreover, if the yield of the grass had to be maintained by means of applications of farmyard manure, experiments in Malaya (2), (3) suggest that the grass will need all the manure resulting from its consumption. It seems that the West Indian mixed farmer will have to manure his standing grass chiefly with artificials and to use his farmyard manure on his other crops, where it is so badly needed and where it cannot be fully replaced by artificials as it can on the grass.

We have suggested that, in the West Indies, a part of the land, which in the past has been growing crops annually worth £5 per acre, will have to be set aside by the mixed armer for feed for stock. Unless the farmer finds the livestock itself profitable, it will be difficult or impossible to induce him to adopt mixed farming. In the West Indies generally, the areas of peasant land where animal ploughing is a practical proposition are exceptional. Meat has to compete with the by-products of the large packing industries. It seems to follow that the peasant must be advised to concentrate mainly on the production of milk, the highest priced animal product. There are, in many districts, more than enough people who are better off financially than peasants, to buy and consume all the surplus milk produced in the neighbourhood. But, in country districts, the local retail market for fresh milk, and indeed for all other products, is a limited one, with little elasticity in demand; a relatively small expansion in the production of such a highly perishable product might cause a disproportionately large fall in price. The provision of a market for milk, in the form of a clarified butter factory or a condensed milk factory, wherever there is any economic opportunity for it, would do much to encourage the adoption of mixed farming. The peasant is used to the production of a staple that is always readily saleable wholesale. If his milk is equally easily sold, the change to mixed farming will seem much more attractive than if he has necessarily to find retail customers for his milk and to cope with the troubles and difficulties which are inseparable from that trade, whether it be on a large scale or on the smallest. Concentration on the production of milk as an essential part of his system of farming would not, of course, preclude the keeping of poultry, pigs, rabbits or goats as backyard stock.

### Increased Production of Food

The recommendations of the Commission were published in a very condensed form in 1940, but its full reports have not been published. The publication of the recommendations happened to be immediately followed by the strenuous wartime campaign in favour of increased local production of food, which was and is still both a necessity and a patriotic duty. There is a danger that these circumstances may give rise to an

(2) Article by C. D. V. Georgi, A. B. Lucy and Gunn Lay Teik in *Malayan Agric. Jour.*, XXIX No. 8, 1941, summarized in *Trop. Agriculture*, XIX, No. 3, p. 50.

(3) *Trop. Agriculture*, XIX, No. 3, p. 51.

impression that in the unpublished report, the Royal Commission has recommended mixed farming and increased production of food as meaning, for practical purposes, substantially one and the same thing. There is no need to await the publication of the full report in order to show that this impression must be false. Mixed farming defines a method of production, not the things produced. There the matter might be allowed to rest were it not for the fact that any such confusion of ideas must jeopardize the prospects for the introduction of mixed farming.

It is obvious that a substantial part of the peasant's output must be sold either locally or overseas to enable him to pay his rent and taxes and to buy his clothes and household necessities; and, still more important for our immediate purpose, to pay for imported artificial fertilizers.

The relationship between saleable products and the use of fertilizers is intimate and important. It is not merely that the peasant obviously cannot buy fertilizers unless he has money wherewith to pay for them. Far more important is the fact that no peasant—perhaps no farmer of any kind—will be ready to spend money on the purchase of twenty shillings' worth of fertilizers unless he expects, if his operations are reasonably successful, directly to increase his production of saleable products by, say, thirty shillings. This advantage of a cash return would apply equally to either the use of fertilizers on grass and the resultant animal products or to fertilizers applied to arable crops and the increased output therefrom.

It will thus be seen that if we are justified in our assumption that, in the wet tropics, a sound system of mixed farming will essentially involve a considerable use of artificial fertilizers, then the sale by the peasant of a considerable proportion of his products also becomes an essential factor in the system. Increased food production, on the other hand, will be a consequence of mixed farming. We recognise that for those whose concern is with broad political or social problems, nice distinctions between a system of farming, its objective and its consequences are of little moment. But in planning a campaign of field experiments and demonstrations, such distinctions cannot be ignored.

Mixed farming, as we visualise it for peasants in the British West Indies, will necessitate the maintenance of a larger number of livestock and lead to their more efficient management. Thus with each increase in the number of peasants practising mixed farming, there will undoubtedly be an expansion in the production of foods such as milk, meat, poultry and eggs, on the increased consumption of which the Commission laid emphasis. Again, we consider it essential that each peasant family should live on an undivided holding, and this, by reducing praedial larceny, and permitting the family to give closer and more constant attention to the land, will undoubtedly encourage the cultivation of a wider range and a larger quantity of vegetables.

If it be admitted that the West Indian peasant cannot produce wheat flour, but will continue to eat bread; and that it will sometimes even pay him to sell his livestock products and to buy imported salt pork* and salt fish; then it will be seen that the production of even a much greater variety of foods than at present will absorb only a small portion of his land and energies. One-fifth of an acre or thereabouts, cultivated intensively, could supply the modal West Indian peasant family of six with all the vegetables, starchy and green, that it needs; and this area would take less than one "man-equivalent" of labour, leaving all the rest of the family manpower available for other purposes. This means that a vegetable garden should be, in the West Indies as elsewhere, an adjunct of every farm, large or small.

Furthermore, on psychological grounds, it would be most unfortunate if there should be any idea in the peasant's mind that the new system of farming is intimately connected with specialization on food production. For in the West Indies, the idea of food production is commonly associated with the idea of a low standard of living. A man who gets a cow, gives her plenty of bedding, and uses the manure to grow whatever crops pay him best—whether it be sugar cane, bananas, arrowroot, cotton or yams—that man is improving his agriculture and raising his standard of living. The peasant will understand that. But the probability of inducing the peasant to give a trial to the system would inevitably be reduced if the agricultural expert, when he is inviting the peasant to give it a trial, had to say to him:—"When you have some farmyard manure you should of course use it to grow food, not things that you sell."

For all these reasons we repeat that if mixed farming is to be introduced into the West Indies it is most desirable that it should neither be confused with the war-time campaign in favour of growing more food, nor with the political creed of self-sufficiency which was necessary in pre-war conditions. We are confident that adequate investigational work will result in a system of mixed farming which will commend itself to the peasant on its merits as a practical method of increasing production; and it is on this ground that the agricultural officer must be able to recommend it.

Our object in writing this article has been to narrow the field of investigation into mixed farming on *a priori* considerations. In the course of our discussion, we have perforce made many sweeping generalizations, some of which we can justify only by the indirect evidence of observation and experience. When the validity of these generalizations has been proved or disproved by the test of direct investigation, we shall be well on the way towards our basis for a system of mixed farming in the wet tropics.

* The cheap by-products of the large packing industries of North and South America.

**Summary**

In conclusion we are of the opinion that the preliminary investigations on mixed farming systems for the West Indian peasant should be based on the following presumptions:—a part of each holding will be cultivated under long term, erect, perennial, fodder grasses intended primarily for feeding on the soiling system, i.e., by the daily cutting and carrying of the young green herbage to the livestock; the arable crops will have first claim on the farmyard manure, of which as large a quantity as possible, consistent with practical economy, should be manufactured annually; the fodder grass will be heavily manured, mainly with regular dressings of artificial fertilizers applied in quantities and proportions designed to maintain both high yields and good nutritive quality in the herbage; the predominant type of livestock will be dairy animals, in addition to a proportion of small stock varying in number and in kind in accordance with the environmental conditions; a substantial part of the crop and livestock produce will be sold off the holding, either for local consumption or export, whichever is the more profitable to the farmer.

## FIELD EXPERIMENTS ON SUGAR CANE IN TRINIDAD

### Annual Report* for 1942 by P. E. Turner, Sugar Agronomist to Department of Agriculture and Sugar Cane Investigation Committee of Trinidad

This comprehensive Report, containing much information of both agricultural and scientific value, comprises 232 pages and in its main features follows the lines of the reports for previous years.† It is divided into nine sections—(1) Ground Limestone, (2) Sulphate of Ammonia, (3) Potash, (4) Phosphate, (5) By-products as Manures (6) Cultural Methods, (7) Planting Methods, (8) Varieties and (9) Summary. In each of the first eight sections the effects of the various treatments or varieties on yield of cane, on quality of crop and on yield of sugar are fully discussed. In the final section the general conclusions to which the experiments give rise are summarised with special reference to the soil type‡ on which they were conducted. There are four appendices to the Report—(1) Output of Cane and Sugar (1928-1941), (2) Increase in Use of Ground Limestone and Inorganic Manures (1928-1940), (3) Proportional Distribution of Sugar-Cane Varieties reaped on Estates (1935-1942) and (4) Rainfall (1929-1941).

Layouts enabling orthodox use of the Analysis of Variance have invariably been used in the design of the experiments. All the experiments have been laid down on areas commercially under cane thus enabling the plantation staffs to take a personal and direct interest and to cooperate fully in the work.

The manurial experiments which have been laid down since 1927 may be classified into four general groups—(*a*) experiments with a large number of treatments and complex layouts to obtain fundamental information, (*b*) subsidiary experiments with a limited number of treatments to elaborate the more important principles to which the experiments of the first group have given rise, (*c*) experiments with few treatments and a large number of replicates to enable quantitative recommendations as to optimum size of dressing, number of applications, method and time of application, etc., and (*d*) permanent experiments to measure, with special reference to the relative merits of organic and inorganic manures, the effects on soil structure, soil characters and soil fertility, and on cane yield and quality, of manurial dressings applied annually over a long period of years.

Quantitative recommendations with regard to the use of lime, nitrogen, potash and organic manures have been made by the author in earlier publications. Recommendations as to the use of phosphate are included in the Report for 1942. It has been established that paying results are obtained when 20 lb. to 40 lb. to the acre of water-soluble $P_2O_5$ are applied to plant cane and to ratoon cane on very acid soils with lime requirements of the order of 10 tons calcium carbonate to the acre to which not more than half the lime requirement has been applied, and to soils saturated with lime and containing free calcium carbonate. On such very acid and calcareous soils the amount of gain of plant cane and sugar from phosphate has been shown to be dependent on time of application of this manure which should be varied according to the moisture status of the soil during the early weeks after planting. On soils of intermediate lime status data have been accumulated which make it evident that response to phosphate is dependent not only on the lime status but also on the potash status of the soil, on the treatment with organic manure and on the size of dressing and time of application of the phosphate. It is shown that inappropriate use of phosphate on soils of intermediate lime status can cause loss in yield of cane and sugar. Specific examples of response to phosphate on five representative soil types are recorded.

* Copies of this Report may be obtained on application to the Author, Sugar Cane Investigation Committee, Department of Agriculture, St. Clair, Trinidad, B.W.I.

† *Tropical Agriculture*, (1940), Vol. XVII, No. 2, pp. 25-26; (1941), Vol. XVIII, No. 7, pp. 141-142; (1942), Vol. XIX, No. 2, pp. 36-37.

‡ A description of the soil types is given in *A Preliminary Survey of Soil Types of Sugar Estates of Trinidad with special reference to the Allocation of Sugar-Cane Varieties* by P. E. Turner and C. F. Charter; and *A Brief Description of the Sugar-Cane Soils of Trinidad* by C. F. Charter in Field Experiments on Sugar Cane in Trinidad, Annual Report for 1941.

As a direct consequence of the results of the manurial experiments the amount of ground limestone used on sugar-cane soils increased from 1,500 tons in 1926 to 9,953 tons in 1940. In 1928 only 600 tons of sulphate of ammonia were imported. In 1940, and in 1941, over 10,000 tons of this manure or its equivalent were imported. Increase in the use of potash and phosphate has been arrested by war conditions.

During the period 1935-42 precise information has been obtained as to the merits of a very wide range of cultural operations including drainage, ploughing (gyrotilling, tractor ploughing, chiselling or knifing and hand forking), furrowing and holing, spacing interval, mulching, &c. Relatively simple layouts with Latin squares and randomised blocks have been used in these experiments.

The varietal investigations have had three main aims. The first aim is the improvement of soil productivity, by the introduction of more satisfactory manurial and cultural practices, to facilitate the substitution of hardy varieties of relatively low quality by more exacting varieties of higher quality. In this way it was possible to increase the plantation area under noble cane from 54 per cent. in 1935 to 61 per cent. in 1939. The second aim is the replacement of the standard varieties by others with superior field and factory characters. To this end very great progress has been made for the standard varieties B.H.10(12) and Co.213 are being replaced largely by B.34104 and to some extent by B.3439. Another variety, B.3337, is showing great promise. The third aim is the scientific allocation of varieties on the basis of soil type.

At the present time increasing attention is being paid to the third aim. A preliminary soil survey of the plantation areas was begun in 1938 and completed in 1942. A detailed field-to-field soil survey is now in progress and the soils of two plantations have already been mapped in this manner. The soil survey is essentially practical in character. The soils recognized are viewed primarily as media and sites for the economic production of sugar cane, rather than as pedological specimens. Since most of the 60 or more soils recognized have a purely local significance they have been given locality names, which as far as possible are those of the sugar estates on which they are most typically developed.

By conducting the survey from the agronomical standpoint it has been possible to distinguish considerable and characteristic differences in the nature of sugar-cane growth on many of the soil series. This information will be of value in selecting varieties for trial on the various soils and as an aid in breeding new canes. In addition, certain soils distinguished by the survey appear to form highly suitable media for froghopper breeding and the canes produced on them to be more subject to attacks by this pest than those grown on other soils. This information will prove of considerable assistance in the allocation of varieties shown by experiment to give good yields after froghopper injury.

When investigations on the selection and trial of suitable varieties for the sugar-cane region of Trinidad were first commenced, it was not possible, owing to lack of information and the complexity of the area, to distinguish well-defined environments for which specific varietal types could be selected and bred. As a result of the soil surveys carried out under the direction of the Sugar Agronomist it is now possible to arrange the different soils recognized in six environmental groups, each with distinct agricultural features and on each of which sugar-cane growth has well-defined characteristics. These groups are based largely on soil moisture supplies as affected by topography and soil texture and structure. A brief account of these soil groups by Mr. C. F. Charter is included at the end of the Report.

As a consequence of the field investigations with manures and cultural methods the output of sugar in Trinidad increased from an average of 75,374 tons a year for the period 1926-30 to an average of 132,505 tons a year for the period 1936-41. It is anticipated that the detailed soil survey, in conjunction with carefully located variety trials on representative soil types, will enable specific varietal recommendations to be made on a field-to-field basis which will prove as valuable to the sugar industry as the quantitative manurial recommendations already mentioned.

## CROWN BUDDING FOR HEALTHY HEVEA

An account is given in *Agric. Amer.*, 2 : 191-3 of the building up in Brazil of high-yielding Hevea plantations immune to South American leaf blight, *Dothidella ulei*, to which high yielding clones obtained from the Far East often proved particularly susceptible. The successful method is to plant a part of all new areas with the highest yielding but susceptible Eastern clones and then to crown bud them after one year with tops from highly resistant though lower yielding strains. At first *H. guianensis* and *H. spruceana* and other immune species were used, but immune *H. brasiliensis* is preferable. No reduction of yield or quality of rubber has been noticed. Older established trees are also topworked and by thus eliminating the tops of the spore-producing trees the number of disease spores should be greatly reduced and the possible development of virulent strains correspondingly lessened. Crown budding is also used to hasten the production of flowers for hybridization ; trees of 4 to 10 years so treated will flower within 3 years against the 6 or 7 years required to flower year-old buddings and in much greater abundance. In a like manner the rapid production of budwood of a desired clone can be brought about. Clonal buds placed on older trees in good growing condition will produce several hundred usable buds within 12 months. The budding technique is described and illustrated.—(*Horticultural Abstracts*, Vol. XIII, No. 1, 1943.)

# CHEMICAL NOTES

*(Compiled by the College Department of Chemistry and Soil Science)*

## Food Yeast

Because in contrast with animal protein, plant protein is poor in some of the B vitamins although rich in others, it is important to supply the missing types to human and animal diets when plant protein is consumed. Recently it has been found that micro-organisms build up all the members of the vitamin B group and that their protein is of the same high nutritive value as animal protein. These facts have been the basis of recent work at the Chemical Research Laboratory, Department of Scientific and Industrial Research, which has led to the production of "Food Yeast". For the factory in Jamaica, an organism has been developed at the Laboratory from a yeast used during the War of 1914-18 for feeding purposes, though at the time nothing was known about its vitamin content. The organism developed is double the size of the originally tried. This facilitates large-scale manufacture and the product is somewhat richer in some of the B vitamins than the original type. When dry it contains as much as 50 per cent. of high-grade protein, approaching in nutritive value to meat and fish protein. Its vitamin B content is definitely higher than that of animal protein, including liver.

The product known as 'Food Yeast', which has resulted from the researches of the Chemical Research Laboratory, has a slightly meaty taste and is of a light straw colour. It can be mixed with water or milk or added to soups and stews, to which it imparts a pleasant meaty taste. It could be successfully incorporated into biscuits and could, if added to flour, yield a most palatable loaf; 5 per cent. of it, added to a 2 lb. loaf, would increase its nutritive value as much as would the addition of a $\frac{1}{4}$ lb. of beefsteak or two eggs. Food Yeast can be produced from waste molasses when nitrogen in the form of ammonia or ammonium salts is added, and its production is extremely rapid. A continuous process has been developed: a solution of molasses and the necessary ammonia and phosphate enter one end of a vat, and an equivalent volume of yeast in suspension is withdrawn from the other. Thus a product containing a high concentration of B vitamins and a high-grade protein is made in a matter of hours. This may be significant during the immediate post-war period when the depleted animal stock of Europe will be insufficient to provide meat and milk for the underfed populations of the occupied countries. In the tropical and sub-tropical countries it may also find an important application, for native diets are often deficient in vitamin B. It is estimated that Food Yeast can be supplied at 6d. per lb., and $\frac{1}{2}$ oz. taken daily would ensure to the native a sufficiency of B vitamins.—(*Nature*, Vol. 151, No. 3827, 1943.)

## New Hemisphere Rubber Source

*Cryptostegia*, a flowering vine in California, Mexico, and Central America may become one of the most important sources of natural rubber for the Americas. It is considered one of the best plant sources of latex.

Most important of the *Cryptostegia* projects, contracted for by the United States Rubber Reserve Company, and the Haitian-American Development Corporation, is the planting up to 100,000 acres of the vine in Haiti. In the United States, 60 skilled horticulturists are being recruited and it is estimated that about 100,000 Haitians will find employment when the work is fully organized.

In rainfall, soil and climate, Haiti is believed by agricultural authorities to be one of the more favourable areas for rubber-growing in the Western Hemisphere. Already small amounts of *Cryptostegia* rubber from matured vine have reached the United States for testing. The quality of the rubber is said to be good, comparing favourably with rubber from *Hevea* and *Castilloa* trees.

Experimental plantings will soon be under way in Cuba, Puerto Rico, Jamaica, Costa Rica, Honduras, and Mexico. These will augment test cultivations now under way in Florida, Texas, Arizona, and California, under the auspices of the Department of Agriculture.

Lacking previous commercial experience, the rubber yield from *Cryptostegia* can only be estimated. Experimenters believe the plant can be safely cropped after the first year and mature plants may yield some 250 pounds of rubber per acre.

Rubber from *Cryptostegia* cures well, the authorities say, has good tensile strength, and is comparable with *Hevea* rubber. Its resin content is suitable for mixing with synthetic rubber.

The plant also offers some possibilities for by-products—kapok from the floss found in the seed pods; fibre for rope from the stems; and alkaloids as drugs.

Production of *Cryptostegia* requires little steel or other strategic materials and little skilled labour. It is estimated that one man per acre will be sufficient to harvest the leaves.—(*Ind. Eng. Chem., News Edit.*, Vol. 20. No. 24, p. 1691).

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## Vitamin C from Green Tomatoes

Vitamin C in green tomatoes does not increase perceptibly through ripening. When pulped as for chutney 92 per cent. of the vitamin C may be destroyed in 7 minutes whereas in red ripe tomatoes only 27 per cent. is lost. Unripe tomatoes, therefore, when being made into chutney should not be sliced too finely and should be put immediately into strong vinegar and the sugar added without undue delay. No tomatoes should be discarded merely because they are small or unripe.—(*Hort. Abst.* Vol. XIII, No. 1, 1943.)